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The use of digital learning technology to minimize problems caused by heavy budget cuts on teachers

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INTRODUCTION

In this paper we report about a large scale teaching experiment conducted at a large introductory mathematics course which took place in the academic years 2016-2017 and 2017-2018. The experiment was initially forced by external needs: Due to general budget cuts we (the course managers and authors of this paper) received a though assignment: To reduce working hours for external teaching assistants with one third - without compromising the teaching quality. Of course that seemed impossible, but we had to try. We were not offered any time for pilot projects etc., we had to find a solution that could be implemented soon and for all 1100 students at the same time. Thus, the budget reduction gave rise to a course redesign problem: How could we over short time reorganize a large course in order to reduce the number of contact hours between teaching staff and students whilst maintaining the quality of learning and teaching.

Since we did not want to cut in the scheduled teaching time, the only way we would have a chance to resolve the redesign problem was through extended use of technology. But what kind of technology should be chosen and how should it be used? We knew, as stated in a thorough OECD-report, that technology does not necessarily improve learning: “The

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connections among students, computers and learning are neither simple nor hard-wired; and the real contributions ICT can make to teaching and learning have yet to be fully realized and exploited" [1]. Accordingly, it was clear to us that we should pay close attention to the way in which we would implement a new digital tool, and that it should be carefully based on an analysis of local needs and conditions. We found that this could be done in three steps: 1) First we had to get an overall status of the mathematical competencies that we want the students to obtain during the course and find out where teachers are needed the most, 2) next we had to analyze how the use of digital tools could actually support the current learning goals, and 3) finally, in the implementation, we should not underestimate practical constraints such as numbers of students, available classrooms, ICT- infrastructure and network connections. In the paper we will describe how we took these steps, completed a new informed course setup/redesign and how we have evaluated our efforts.

1 MATHEMATICAL COMPETENCIES, WHERE ARE TEACHERS NEEDED?

1.1 The concepts of mathematical competence and competencies

With the now famous KOM report from 2002 it became clear for many educators that teaching and learning mathematics should be regarded in a much broader sense than it was common previously where the main focus often was on trivia knowledge and procedural skills. Now the goal for mathematics teaching on all educational levels from primary school to university should rather be obtaining mathematical competence defined as “the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations where mathematics plays or could play a role” [2]. In 2013 it was confirmed that these ideas still are highly relevant, not at least on technical universities, when the SEFI Mathematics Working Group (MWG) adopted the concept of mathematical competence as a foundation for the group’s new curriculum framework [3]. As stated by the principal editor of the framework (B. Alpers) there were mainly two reasons for this:

“On the one hand, it emphasizes the ability to apply mathematical concepts and procedures in relevant contexts which is the essential goal of mathematics in engineering education: to help students to work with engineering models and solve engineering problems. On the other hand, it explicitly recognizes that competence requires a solid base of knowledge and skills reflecting the strong opinion of many “practitioners” engaged in the MWG” [4].

In order to make the concept of mathematical competence more operational it is differentiated into eight specific competencies ([2], [3] and [4] for detailed definitions):

1. Thinking mathematically
2. Reasoning mathematically
3. Posing and solving mathematical problems
4. Modeling mathematically
5. Representing mathematical entities
6. Handling mathematical symbols and formalism
7. Communicating in, with, and about mathematics
8. Making use of aids and tools

In the next section we will analyze the status regarding mathematical competencies for the course in question in this paper.

1.2 How are the mathematical competencies reflected in the course Math1?

The course, which is the subject of this paper, is a first year course in mathematics, Math1, at a technical university (Technical University of Denmark, DTU). It counts 20 ECTS points, and it is obligatory for all bachelor study programs at the university. Inspired by ideas behind the Danish KOM report [2] the course from the very beginning back in 2001 combines different approached to the teaching and learning of mathematics. It contains four teaching elements, each of them having its' own evaluation form testing different competencies. We list the four elements here together with a tentative list of the most relevant competencies involved:

- Standard teaching with lectures followed by group exercises covering 2/3 of the total teaching time. Mathematics is built up linearly, step by step. The outcome is evaluated in two individual written exams. Competencies involved: 2, 3, 5, 6.
- Seven homework assignments distributed throughout the academic year focusing mathematical subjects just been treated. The students are expected to unfold, explain and visualize the mathematical concept and methods. Corrected, commentated and evaluated by Teaching Assistens (TAs). Competencies involved: 2, 3, 5, 6, 7.
- Seven thematic exercises given throughout the academic year focusing on mathematical subjects just treated. Examples: Modelling electric networks by using systems of linear equations or modelling forest fire by vector fields. Evaluated by a quiz which tests that the exercise has been worked through. Competencies involved: 1, 3, 4.
- A large four-week group project-exercise at the end of the course where several main topics are brought together in order to investigate a rea-world problem. The group report is evaluated by TAs and followed by an oral examination. Competencies involved: 1, 2, 3, 4, 5, 6, 7. The idea and design of Math1 project-exercises is described in [5]

As shown here, each mathematical competence is unfolded in at least two of the four teaching elements, and we find that the elements play together in a fruitful way. Please note, however, that there is one missing: We have omitted competence number eight (aides and tools) from the analysis of the competencies involved in the course since. The reason for that is that the meaning, amount of use and influence of aids and tools have changed dramatically through the last decades, i.e. since the KOM report. This is especially the case in Denmark where CAS tools like Maple, TI Nspire or GeoGebra are fully integrated in the high school teaching and at universities and often allowed in homework papers, reports as well as in exams. CAS means "Computer Algebra System". The core characteristic of a CAS is it can calculate and reduce symbolic algebraic expressions, but must CAS can also be used for numeric calculations and advanced visualizations or even animations.

Today technology is (a least in Denmark) a part of all teaching elements, and here we would like to emphasize the intensive use of CAS. CAS supports and potentially expands the meaning of the above mentioned competencies and the opportunities for acquiring them. But, on the other hand, it has gradually turned out that CAS can weaken the acquisition of elementary skills, cf. B. Alpers's remark above about the need for "a solid base of knowledge and skills reflecting the strong opinion of many "practitioners" engaged in the MWG". Recently a Danish governmental mathematics commission for high school reported that “there is agreement in the Commission that the way CAS has been involved has had a negative impact on students' development and possession of basic skills”. [6] An earlier report from the Danish Ministry of Education stated that university teachers in general are worried about “the students’ deficient handling of formal expressions.” [7]

We conclude that in the center of the new competence field of integrated aides and tools a new deficient area has arisen. It is a new problem that we have to address and we have to s reconsider the teachers' role in relation to the competencies. Where teachers on the floor are still highly important in the introduction of new subjects, in the feedback and evaluation of homework and in the supervision of project work, we found that the new need for consolidating elementary skills more easily can be resolved by mainly using digital tools. Since basic skills usually are introduced in the standard part of the teaching, we found that our chance to reduce working hours spent by TAs without compromising the teaching quality had to be pursued by a redesign of the weekly schedule for the standard part of the teaching which is the subject of next section.

2 REDESIGN OF THE WEEKLY TEACHING SCHEDULE

2.1 Before and after

As mentioned in the section above, we found that the budget cuts should be realized within the standard part of the teaching. We did not want to fire any of the external TAs, but where the TAs before the budget cuts appeared in class twice a week they now only appear once. Hence we had to address three fundamental questions in our course redesign:

1. How can we qualify and optimize the total effort made by the teachers
2. How can we motivate the students to attend sessions without TAs around and take advantage of “learning by peers”?
3. How can we improve the learning of basic knowledge and skills?

Now we will discuss these questions by referring to the before-after teaching schedule as shown in Figure 1. The course had and still has two meeting sessions for the students a week, a Long Day and a Short Day. Before the redesign of the weekly schedule the two days, except for the length (a full day program versus a half day program), had the same structure and goal: A new topic was introduced in the lecture (in big lecture halls) and afterwards the topic was explored in group exercises supported by teaching assistants (in class rooms).

The redesign implicated a new understanding and distribution of the curriculum. As the result of our considerations, we came up with one “topic of the week” which has to be introduced at Long Day. The roles for the lecturer as well as the teaching assistants have accordingly changed. On Long Day the teachers now have to focus on the big picture, the ideas and perspectives for the whole week. We present fewer worked examples but the ones chosen are essential for the attempt to prepare the students for group-work on Short Day without help from the TAs. The Short Day starts with a short lecture, a recap or pep-talk which includes investigating special cases etc. The group exercises, which follow the lecture on Short Day, provide extended online help (hints and results) and they focus important details from the weekly topic including elementary skills from the weekly topic.

Weekly schedule 2015-16		
	Long Day	Short Day
08:00		Lecture: Topic 2
09:00		
10:00	Lecture: Topic 1	Group exercises with TAs
11:00		
12:00		
13:00	Group exercises with TAs	
14:00		
15:00		

Weekly schedule 2016-17-18		
	Long Day	Short Day
08:00		Lecture
09:00		Group exercises without TAs
10:00	Lecture: Topic of the week	
11:00		Weekly Test
12:00		
13:00	Group exercises with TAs	
14:00		
15:00		

Figure 1. Weekly schedule before and after redesign

A crucial point in the new design is the Weekly Test that intends to give the math teaching week an elegant, effective and motivating conclusion by using digital assessment. We now explain this further.

2.2 The concept of The Weekly Test

To give the new weekly schedule an elegant, effective and motivating ending we had to find a professional digital assessment tool, and we chose Maple T.A. Let us here stress that Maple T.A. can be used in teaching independently from Maple (as a CAS) but its functionality includes the Maple kernel which gives the teacher the opportunity to ask complex and varied questions. Our main principles for the test can be summarized as:

- The students are not allowed to use any electronic mathematical tools since the overall subject is the basic skills of that week.
- The students are allowed to discuss the problems in their working groups. The 10 problems are randomized so that they include different parameters for different students. Consequently the students can discuss the methods but not share the results.
- The problems are graded by the Maple CAS kernel so that it is possible to pose more complex and open questions (as mentioned above).
- The students obtain one bonus point to bring to the final exam if they have more than 60% correct in the first attempt in the classroom in the last hour of the class.
- The test reopens later in a home version allowing for several attempt for further training, especially for students who did not “pass” the classroom test, they now have a chance to obtain a half bonus point.

- The final written exams have a Maple T.A. part with a set of problems selected from the weekly tests. Thus, the problems in the exam are regarding the math identical with the ones that have been on the agenda for the weekly test but they will contain new parameters etc. to prevent the students from just memorizing the result. This means that all “canonical” basic skills once more are fully on the agenda in the exam and that the weekly test not only has a summative purpose, but also a formative.

We now show two typical Maple T.A. problems.

Example 1:

Given a matrix A and a diagonal matrix D :

$$A = \begin{bmatrix} 5 & -6 \\ 0 & 7 \end{bmatrix} \text{ and } D = \begin{bmatrix} 5 & 0 \\ 0 & 7 \end{bmatrix}$$

State an invertible matrix V such that: $V^{-1} \cdot A \cdot V = D$

(A matrix $\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$ is written in MapleTA as <<1,3>|<2,4>>)

$V =$

Figure 2. A typical MapleTA problem in Math1

The problem shown in Figure 2 is to find a quadratic 2x2 matrix that can diagonalize a given 2x2 matrix A. There are infinitely many solutions and the upper triangle in A is randomized within some limits.

Example 2:

An open surface F_r is given as the curved part of the surface of a cone of revolution with the height $h = 5$ and base radius $r = 1$.
We think of the cone as being placed with the base centred at the origin and standing on the $(x, y)-$ plane, and with the vertex pointing in the positive direcion of the z-axis.
A vector field is given by the expression:

$$V(x, y, z) = \left(7 \cdot y, 4 \cdot x, x^2 + y^2\right)$$

Compute the total flux in through the curved part of the surface of the cone.
(Hint: Put a bottom on the cone and use Gauss' Theorem).

$\operatorname{Flux}(V, F_r) =$ Number

Figure 3. A typical MapleTA problem in Math1

The problem in Figure 3 is to calculate the flux of a given vector field through a geometrically given surface. We expect the students to find a parametrization of the surface (there are infinitively many solutions) and the vector field is randomized within some limits.

2.3 The choice of tool, local constraints, drawbacks and how they were addressed

As mentioned above it was necessary to give the new weekly schedule an elegant, effective and motivating ending and the solution was the Weekly Test. We chose Maple T.A. since in give us the possibility of asking many types of questions with a high degree of complexity, e.g. questions with randomized parameters and infinitively many corrects answers which will be evaluated the Maple kernel. We had one more specific reason for choosing this tool: Maple (CAS) had for many years had been a fully integrated part of the teaching. Especially we avoided a classical hurdle in introducing digital assessment: That you have to teach a new input language with rules that can cause noise in the testing results (do you need to write the multiplication sign? Etc.) In our course we are teaching Maple with pure text programming and we use the same language for input in Maple T.A. tests. Subsequently an error is an error no matter if it is in the language or in the math.

When you use digital assessment for credit-giving tests and there are no teachers around, you should expect some cheating! For instance you can cheat by using Maple CAS for solving the problem, and then cut and paste the result into the Maple T.A. form. To avoid this we introduced the Maple T.A. facility Proctor Mode where you have to invoke full screen before you enter the test, and if you leave full screen, your answers are submitted immediately and you cannot reenter the test without help from an official. To make this setup work we had to improve internet connections and to have some elder student around as technical support.

3 FINDINGS

3.1 Attendance to the teaching sessions

In the ninth week of the semester we conducted a questionnaire survey where we asked the students about their study behaviour, experiences and attitudes in the previous week, that is semester week eight. One section of the questions was about attendance and here are the results (45% answered):

Table 1. Attendance to the teaching

About Long Day (with TAs):	**Yes**	**No**	**Total**
Did you attend the lecture Long Day	401	130	531
Did you attend the group exercises Long Day	490	43	533
About Long Day (without TAs):			
Did you attend the lecture Short Day	406	125	531
Did you attend the group exercises Short Day	504	29	533

We conclude that surprisingly the attendance on Short Day (without TAs) seems at least as high as on Long Day. This applies to both lectures and group exercises and shows that we have succeeded on one crucial point: To make the students attend that part of the scheduled teaching where we had removed the support of present TAs.

3.2 Motivation in relation to activity type

The questionnaire also asked the students about their experience of motivation in week eight in relation to the four most important teaching activities during a standard week: Preparation for the classes, the two lectures, the group exercises on Big Day (supported by TAs) and the group exercises on Short Day (without TAs) including the Weekly Test. We asked the students to put the activities into a priority order. In Table 2 we show how many first priorities, second priorities etc. each of the activities obtained (41% answered).

Table 2. Popularity of teaching activities

Type of activity	1. priorities	2. priorities	3. priorities	4. priorities
Preparation	24	39	63	290
Lectures	153	113	139	35
Group ex. Long Day	146	160	101	31
Group ex. Short Day	167	106	108	54

We notice that the group exercises on Short Day, again rather surprising, got most first priorities. This fits well with the high attendance on that day and indicates that we have succeeded in one more important ambition: To develop class room teaching without present teachers which the students experience as highly motivating.

3.3 Conceptual understanding versus basic skills

Finally, the questionnaire also asked the students about their self-evaluation regarding their learning of previous weeks' new mathematical concepts and regarding their learning of the weeks' basic skills and methods.

In Table 3 we show how the students answered the question (41% answered): *To which degree did the teaching activities support your learning of concepts and their mutual connections in the previous weeks' topics?* And in Table 4 we show how the students answered the question (44% answered): *To which degree did the teaching activities support your learning of the basic skills in the previous weeks' topics?*

Table 3. Learning of concepts

Degree		Numbers
1	To high degree	171
2	To some degree	257
3	To lesser degree	58
4	Not at all	4

Table 4. Learning of basic skills

Degree		Numbers
1	To high degree	203
2	To some degree	263
3	To lesser degree	54
4	Not at all	5

In both tables we find that a big majority of students think that their learning should be placed in the two upper boxes. In order to interpret these numbers in full we should have had similar surveys from the previous year or control groups. Unfortunately, this was not possible due to the time pressure in the teaching experiment. However, we must provisionally welcome the fact that the students experience that both sides of the education have succeed in an apparently balanced way, maybe with a little favour to the basic skills.

4 SUMMARY

We have conducted a big scale teaching experiment in which we have reduced the amount of working hours spent by teachers at a big mathematics introductory course (Math 1 at DTU) with the purpose of maintaining the quality of teaching and learning. We found that this could only be done by a course redesign where we had to introduce a new digital learning tool. In order to do this in an informed way and thereby increase the chances for success, we started with an analysis of the overall competencies that we want the students to obtain and in which teaching elements the physical presence of the teachers are really needed.

The starting point was the concept of mathematical competence and the eight different mathematical competencies it contains as founded in the KOM report and applied on engineering education by the SEFI MWG. Given the high level of the use of digital tools in math teaching in Denmark in general and in the course in question especially we suggested that the eighth competence, aid and tools, is not an isolated competence next to the other seven, but that it in today's teaching and learning are integrated in them and even changes them. In the new field of competencies integrated with aids and tools we saw a new problem that we had to address: The evolving lack of elementary mathematical skills.

From this point the choice of a new digital tool and the redesign of the weekly course program as shown in Figure 1 were not that difficult. By introducing an advanced digital assessment tool (Maple T.A. was chosen) to be used in a weekly test, it seemed like we could resolve two problems at the same time, the reduction of hours spend by teachers in the classrooms and addressing the need to strengthen the basic skills. In the new weekly program teachers are still needed and "on the floor" when we introduce new subjects, in the feedback and evaluation of homework and in the supervision and evaluation of project work. But other tools can take care of the elementary skills in a probably more efficient way: Extended online help, learning by peers and digital assessment.

From the questionnaire survey we have further concluded that the new course setup:

1. Apparently provides a less monotonous teaching, emphasizing different competencies and working forms.
2. Ensures a very large attendance to both classes with and without teacher support.
3. Is experienced by the students as very motivating.
4. Apparently supports the conceptual part of the teaching as well as the elementary skills in a balanced way.

As a whole, we will assert that we have shown that by digitals tools it is possible to minimize problems caused by heavy budget cuts on teachers.

REFERENCES

[1] OECD (2015), Students, Computers and Learning: Making the Connection, PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264239555

[2] Niss, M. and Hojgaard, T. (2002), The Danish KOM report.

[3] Alpers, B. (principal editor) (2013), The SEFI Mathematics Working Group's new Curriculum Framework Document. http://sefi.htw-alen.de/Curriculum/Competency%20based%20curriculum%20incl%20ads.pdf

[4] Alpers, B (2014), Mathematics Curriculum for a Practice-oriented Study Course in Mechanical Engineering. http://sefi.htw-aalen.de/Curriculum/Mathematics_curriculum_for_mechanical_engineering_February_3_2014.pdf.

[5] Schmidt, K and Winsløw, C (2018), Task design for Engineering Mathematics: process, principles and products, Proceedings of INDRUM 2018.

[6] Hansen, H.C. et al. (2011), Modern math skills from school start to university study start (in Danish). https://fou.emu.dk/offentlig_show_projekt.do?id=162957

[7] The (Danish) Mathematics Commission (2016), Final report (In Danish). https://gymnasieskolen.dk/sites/default/files/Arbejdsliv/matematikkommissionen_afrapportering.pdf